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REMOTE SENSING AND GIS BASED EVAPOTRANSPIRATION ANALYSIS IN LUNI UPPER SUB BASIN

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ABSTRACT

Water is one of the most vital natural resources used not only for direct consumption purposes but also as an input in the process of production in different sectors of the economy of which agriculture is the most important. Sustainable water management in a river basin requires knowledge of the water availability and water requirements of the basin in the present and future for various purposes. Evapotranspiration is a key component of water resource management influencing the water demands of agriculture. Evapotranspiration is important to the hydrologic cycle because it represents a considerable amount of moisture lost from a watershed. Remote Sensing and GIS is considered as a vital tool for analyzing the Evapotranspiration. The newly developed MODIS satellite is being used in estimating Evapotranspiration. In this project, various hydrological components of the Luni upper sub basin has been calculated with the help of satellite derived information and Evapotranspiration has been analyzed. The availability of multispectral and multi-temporal satellite images provides a clear synoptic view of the study area and can give a good insight in to the topographic and physiographic characteristics of the area. Climate parameters measured using the satellite based sensors are also highly useful in analyzing the climate variability. The FAOPM (Food and Agriculture Organization – Penman Monteith) model is used to derive the evapotranspiration component spatially with the help of remote sensing and GIS techniques. Rainfall pattern of the study area has been analyzed using IMD daily grid data. The study proves that satellite data derived inputs along with other ancillary data can be effectively used to analyses the Evapotranspiration of a given sub basin and its temporal variations.

KEYWORDS: Evapotranspiration, Climate Parameter, Remote Sensing and GIS

INTRODUCTION

Water is not only a resource, it is a life source. It is the source of life and to extent the source of livelihood. The vagaries of water availability is major over the globe, which leads to variation in approach to achieve survival living. Optimum and efficient use of scarce clean water resources is becoming a major concern these days as the inequality between the demands by ever increasing population to these precious resources is widening day by day. In arid and semi-arid region recurrent drought and water shortage are common phenomena.

This knowledge will help in better management of water resources and the protection against over exploitation and contamination, Cropping pattern – irrigation and drainage practices, Analysis of the effect of land use changes on water availability, Analysis of the effect of climate changes on water availability, Identification of recharge zones and

suitable potential rainwater harvesting sites etc (Ateawung, 2010; Mekonnen, 2005). Also the analysis carried out on land use/land cover, vegetation vigor, climate parameters will help in forming a sustainable development plan for the study area.

Understanding of hydrological behaviors of a basin is necessary steps towards the movement and distribution of water throughout the earth and that address the management of water resources. One way is to acquire a better understanding is to use remote sensing techniques (Tsouni et al. 2003). By using remote sensing data derived hydrological responses, such as land surface temperature, Albedo, emissivity and ground based observation such as wind, temperature, vapor pressure and different components of hydrological cycle comes under the hydrological behavior of a catchment area for the analysis and the calculation of Evapotranspiration.

In recent years the advancement in satellite and computer technology along with different models and software's has opened the opportunity to process and derive different hydrologic parameters on pixel basis. On the basis of these parameters we can calculate Evapotranspiration, and precipitation which can leads to a proper quantification of water balance components an there by proper assessment of the hydrological behavior of a basin.

OBJECTIVE OF THE STUDY

- Calculation and analysis of Evapotranspiration based on MODIS satellite data and other ancillary data.
- Generation and analysis GIS layers for different parameters namely, land use /land cover, topography, slope, drainages, rainfall, temperature, wind speed, soil texture and vapor pressure.

STUDY AREA

Luni Upper Sub Basin is located in south-western Rajasthan, between latitudes 23°32'59.366"N 27°18'26.267"N and longitudes 70°48'54.221"E 75°3'57.517"E. The Basin extends over parts of Ajmer, Barmer, Jalore, Jodhpur, Pali, Sirohi and Udaipur districts in Rajasthan state and ends at the lands of Rann of Kutch in Gujarat. The total catchment area of the Basin is 79886.74 Sq.Km. The index map of the study area is shown in figure 1.

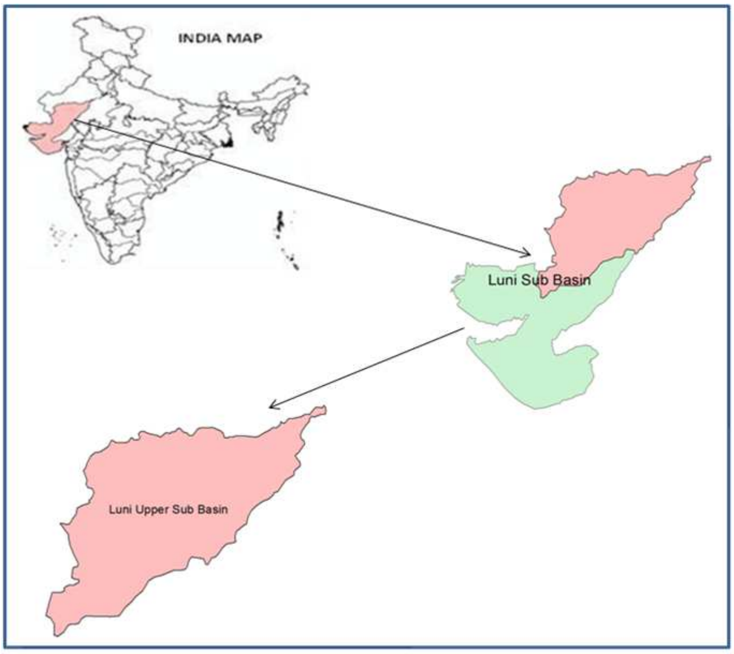

Figure 1: Index Map of the Study Area

Topography

Topography of the study area has been analyzed using SRTM 90 m DEM. Most of area is relatively plain and the part of eastern side is covered with the Aravalli hills. General elevation of the area ranges from 0 m at Rann of Kutch to 1619m at the Aravalli Range.

With the help of ARCGIS hydrology tool, potential drain of the Luni upper sub basin has been delineated using SRTM 90m DEM. The potentials drains overplayed on DEM are shown in figure 2.

Land Use/Land Cover (LULC)

Land use and land cover map of study area generated from IRS P6 LISS III data for the period 2004-2005 is shown in figure 4. Most of the area is coming under agricultural land whereas south part of basin is covered with salt affected land which lies in Rann of Kutch area. The Aravalli range is covered by deciduous forest and the eastern part mostly covered with the open scrub land (Figure 3).

Soil Texture Map

Soil texture map of study area is shown in Figure 4. Soils of the study area have been classified in to four classes: coarse texture, medium texture, fine texture, rocky and non-soil areas. Most of the area is coming under coarse texture category followed by fine texture. The Aravalli range and Rann of Kutch area mostly comes under the rocky and non-soil texture.

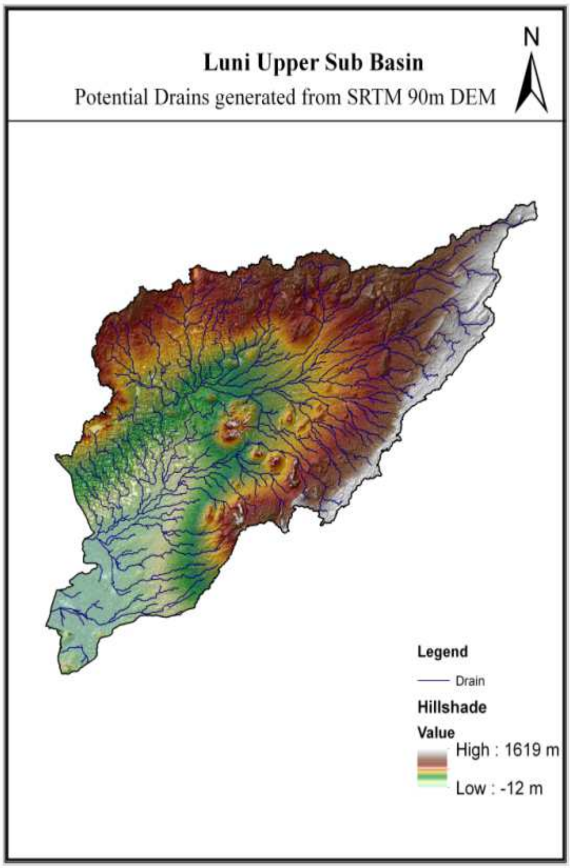

Figure 2: Potential Drains Generted from SRTM 90m DEM

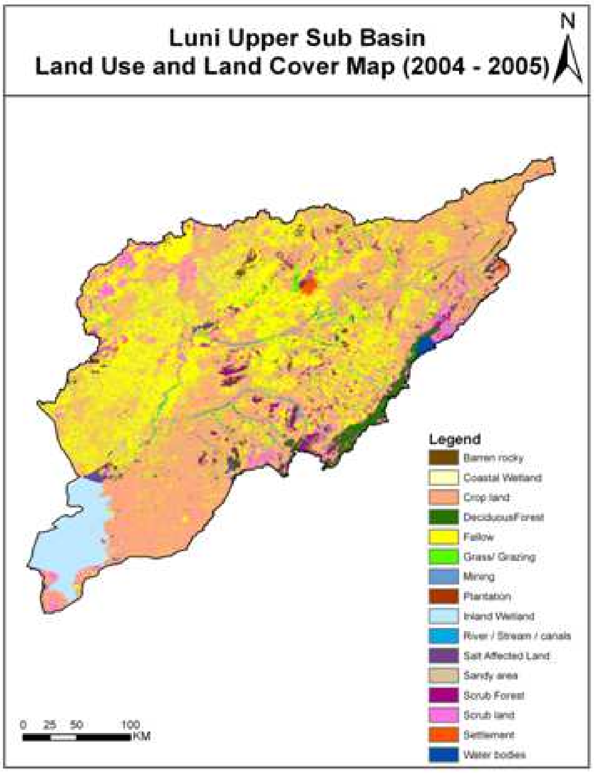

Figure 3: Land Use and Land Cover Map (2004-2005) of Study Area

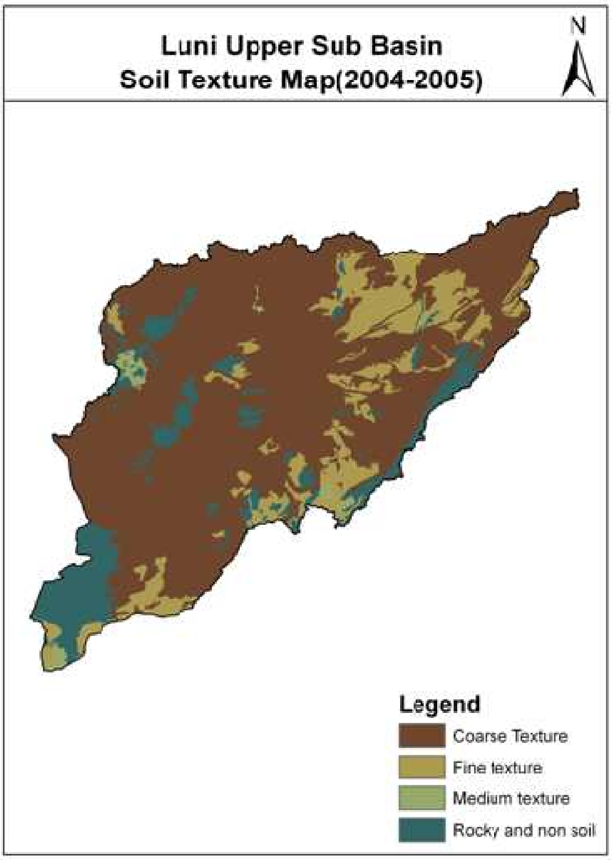

Figure 4: Soil Texture Map (2004-2005) of Study Area

Drains

SRTM DEM 90 m data was used for the generation of drain by using hydrological tools in Arc GIS. A suitable threshold value was assumed to derive the drainage network and it is to be used in delineation of the sub watersheds. Drains give the nature of surface; slope and their spatial arrangement provide the idea about runoff analysis. Figure 5 below shows the potential drains of study area.

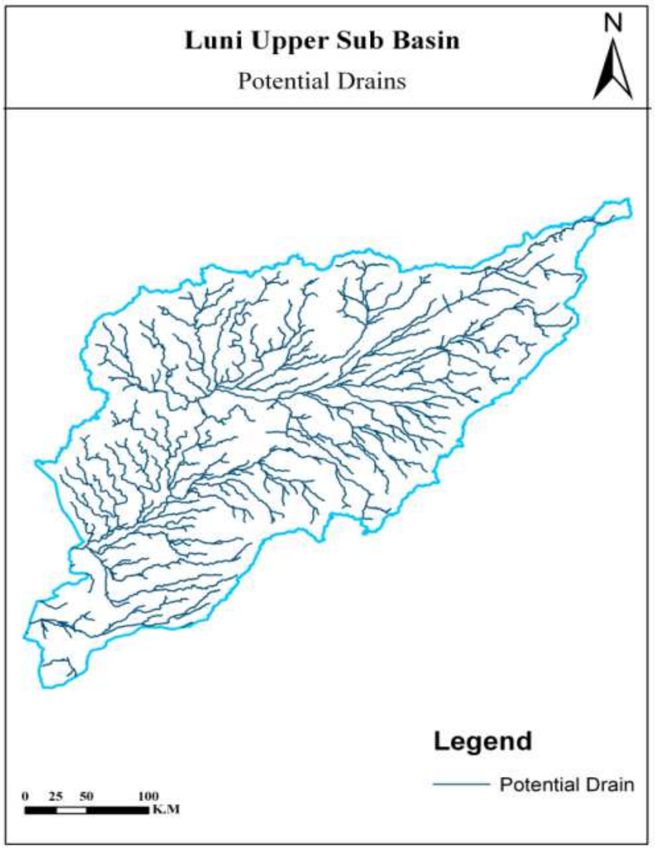

Figure 5: Potential Drains of Study Area

Climate

The Luni upper sub basin is located in a semi-arid zone of western Rajasthan. There are mainly two factors which affect the climate: Rainfall and temperature which are describe as follows.

Rainfall

In the study area the monsoon season takes place between months of June to August. Average annual rainfall of the sub basin in 2003 receives the highest rainfall up to 555mm whereas 2002 was the drought year so least amount of rainfall is received up to 220mm. In the mean monthly variation, it is observed that highest rainfall is received in the month of July. Figure 6 and 7 shows the annual and monthly variation of rainfall (2001-2004) of the study area.

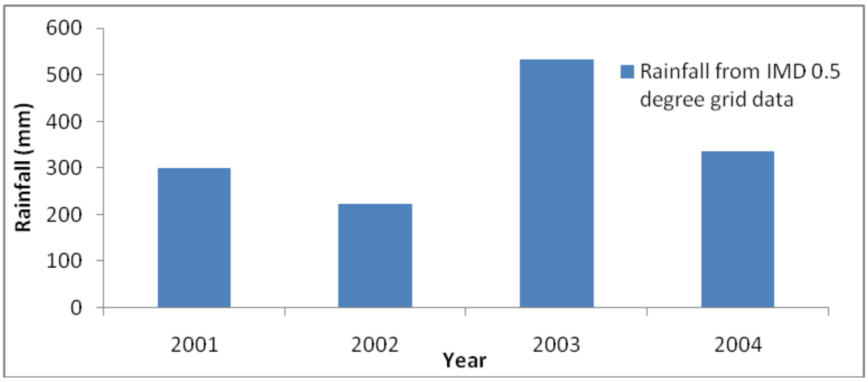

Figure 6: Distribution of Annual Rainfall from (2001-2004) of Study Area

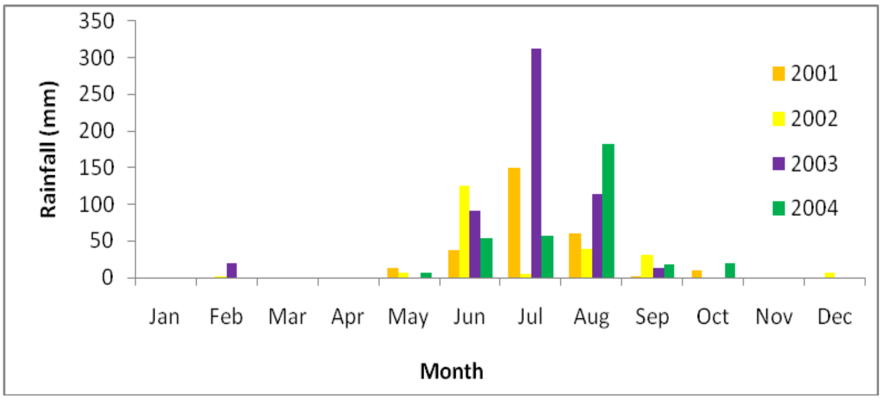

Figure 7: Monthly Variation of Rainfall from (2001-2004) of Study Area

Temperature

Indian Metrological Department (IMD) 1^0x 1^0grid data has been used for the analysis of temperature. Mean temperature is used for the calculation of parameters in the analysis of Evapotranspiration. Lowest temperature is observed in the month of December and January while in the month of April, May and June receives highest temperature.

DATA AND METHODOLOGY

Data

The data required for the study is shown in Table 1

Table 1: Data Used in the Analysis of Evapotranspiration

Sensor/Data	Categories	Source
MODIS	Land Surface Temperature(LST)	USGS Website
	Albedo(MCD43B3)	USGS Website
	Emissivity(MOD11A2)	USGS Website
Ground based observations	Wind Speed	IMD Station data
	Vapour Pressure	Climate Research Unit (CRU)
	Temperature	IMD grid data
	Rainfall	IMD grid data
RESOURCESAT-2(LISS-III)	Land use/Land cover	ISRO
	Soil Texture	ISRO
SRTM	DEM	NASA

*Generated output is validated with ISRO- AWS (Automated Weather Station) and CAZRI observation dataset**.**

METHODOLOGY

Calculation of ET by Penman–Monteith Algorithm

Quantification of Evapotranspiration (ET) (Ref7) is prime requisite for efficient planning and management of water resources. It is important parameter in efficient use of water especially for agricultural in arid and semi-arid regions. We have used Penman–Monteith algorithm (PM-Mu) for calculating potential Evapotranspiration because this is the most consistent method and widely used process. The equation can expressed as:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{(T+273)}u(e_s - e_a)}{\Delta + \gamma(1 + 0.34u)}$$

Where,

ET_0 -Daily reference crop Evapotranspiration (mmday^{-1}), R_n- Net radiation flux density (MJ m^{-2}day^{-1}), G-Heat flux density into the soil (MJ m^{-2}day^{-1}), T-Mean daily air temperature (^{0}C), γ -Psychometric constant [kPa °C^{-1}], u- Wind speed measured at 2m height (m s^{-1}), e_s - Saturation vapor pressure (kPa), e_a- Actual vapor pressure (kPa), Δ-Slope of saturation vapor pressure curve [kPa °C^{-1}], VP_{def} – Saturation vapor pressure deficit (kPa), RH- Relative humidity (%).

The Penman-Monteith method's characteristics listed above, can be integrated into four major meteorological characteristics –

- Mean Daily Air Temperature (*T*)
- Net Radiation Flux Density (R_n)
- Saturation Vapor Pressure Deficit (e_s-e_a)
- Wind Speed (*U*) and psychometric constant**(**γ**)**

The methodology flowchart for evapotranspiration calculation is shown in figure 8

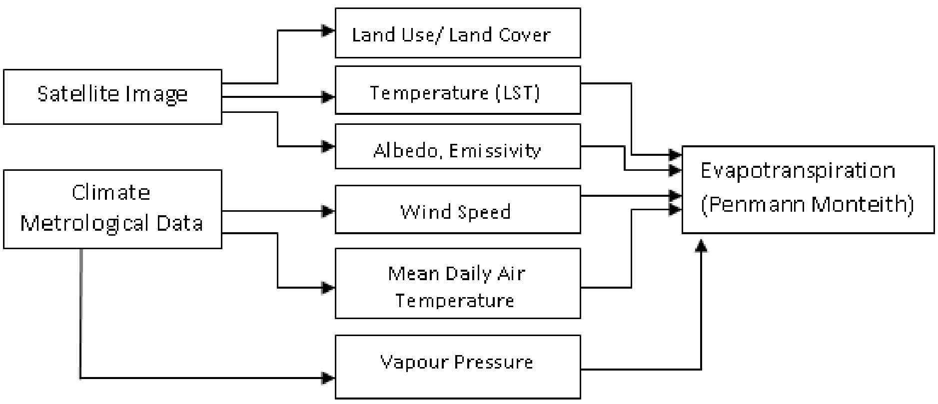

Figure 8: Methodology for Water Balance Estimation

RESULTS AND DISCUSSIONS

Rainfall

Mean Monthly Varition of Rainfall (2001-2004)

To understand the spatial water balance distribution, we need to analyze the distribution of evapotranspiration and

rainfall which occur in a basin. The highest rainfall is received in the month of July and August and least rainfall is received in month of September, October and February. It is observed that the south-east part of the basin receives maximum amount of rainfall. The western part of the basin receives least amount of rainfall. Monthly variation of rainfall is shown in figure 9.

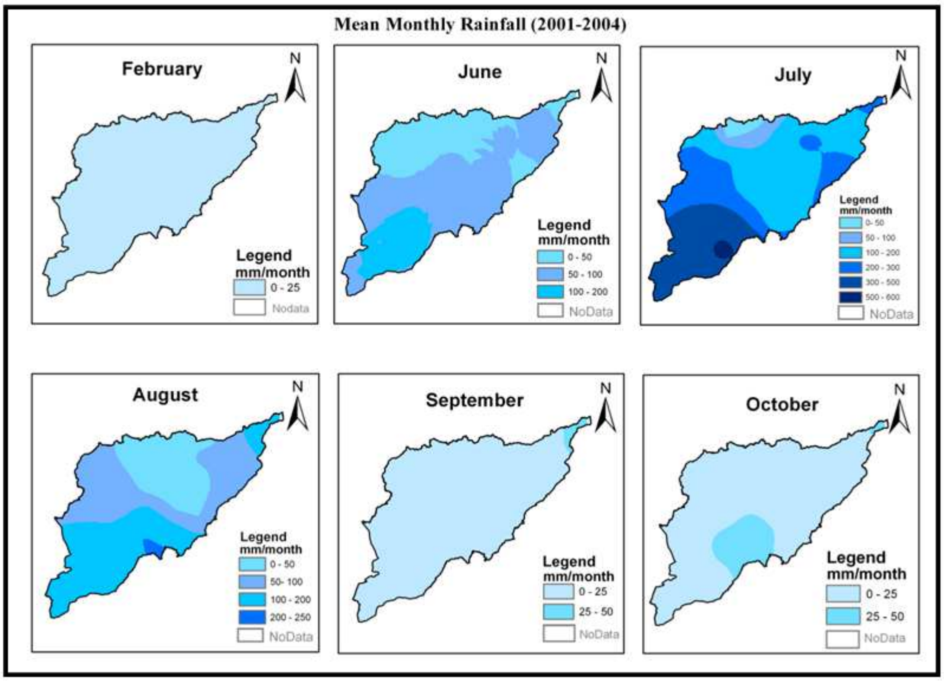

Figure 9: Maps of Mean Monthly Rainfall from (2001-2004)

Calculation and Analysis of Evapotranspiration

The results obtained from ET calculation are presented here for discussion. Evapotranspiration has been calculated based on MODIS satellite data and other ancillary data using Penman-Monteith equation. Foremost we have calculated weekly Evapotranspiration for a particular year. On the basis of weekly ET we have calculated mean monthly ET for four years (2001-2004) for the analysis of water balance. The mean monthly evapotranspiration is found to be varying from 70 mm to 330 mm. It is observed that due to low temperature in the month of January, february,November and December lowest values of ET are observed and they lies betweeen 70 to 150 (mm/month). As this study area lies in semi arid region so in the month of March, April, May and June as the temperature and wind speed are high so ET values are higest and lies between 180-330(mm/month). Mostly evapotrnspiration depends upon temperature, wind speed, vapour pressure, relative humidity and land surface temperature. The highest ET is from the Agricultural land, Deciduous, Forest plantation and water bodies areas whereas the least ET is from Fallow land and built-up areas. Due to lack of cloud free MODIS images in month of June, July and August we have used PET form CRU dataset for the analyis of ET. In month of July and August higest amount of rainfall is received due to this ET values lies between 90 to 210(mm/month). The figure 10 shows the varation of mean monthly calcualted evapotraspirtaion (ET) form (2001-2004) in Luni upper sub basin.

The trend of mean monthly ET in different years (2001-2004) shows almost same pattern and varies according to different months. We can examine that the highest values of ET are observed in the months of March, April, May and June while lowest values are in January, February, November and December months. There is minor variation in ET value in year 2004 due to increase in temperature and wind speed as ET mainly depends upon these factors. The trend of potential

Evapotranspiration (PET) of CRU datasets in different years (2001-2004) shows almost same pattern and varies according to different months. Mainly potential Evapotranspiration (PET) is the amount of evaporation that would occur if a sufficient water source is available and as CRU PET dataset provide averaged PET over 0.5^0 x 0.5^0 grids.

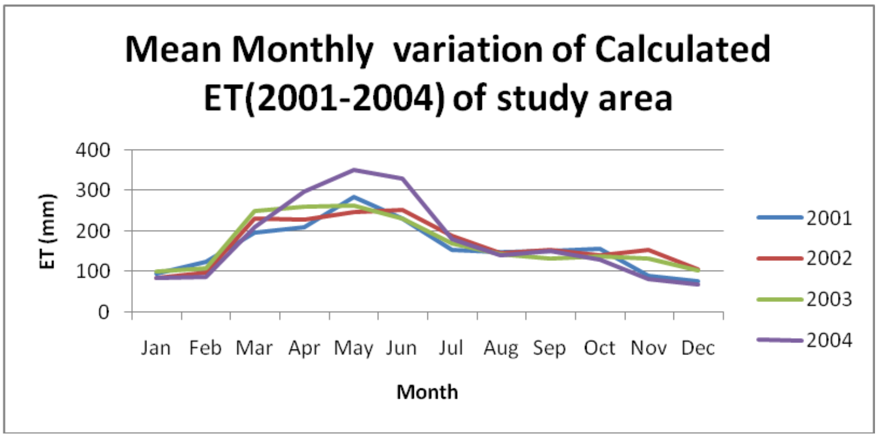

Figure 10: Representation of the Mean Monthly Variation of Calculated Evapotranspiration (2001- 2004) of Study Area

Difference between Calculated ET and Pan Evaporation (2001-2004)

The trend of Calculated ET follow almost same pattern but there is some inconsistency as we taken Pan Evaporation of Cazri. Following graphs shows the difference between calculated ET and Pan Evaporation of Cazri datasets.

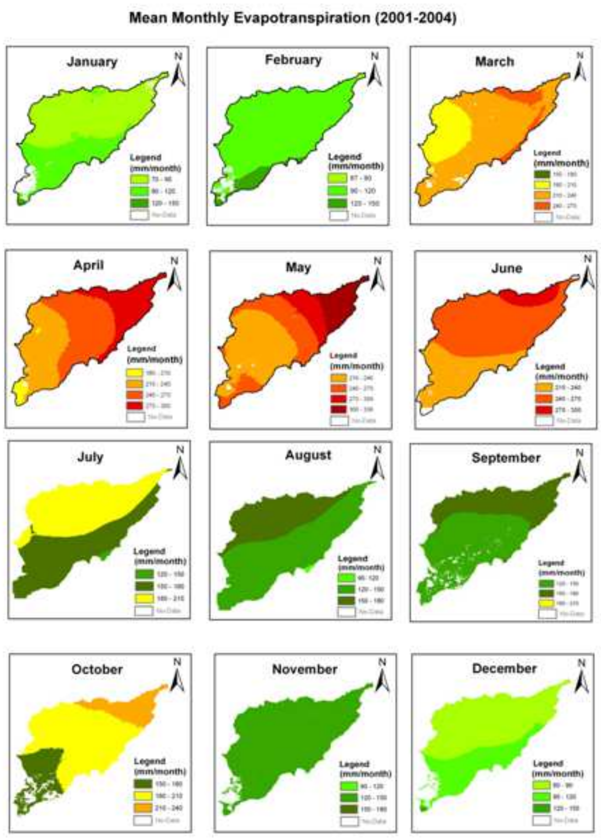

Figure 11: Maps of Mean Monthly Evapotraspirtaion(ET) form (2001-2004)

CONCLUSIONS

Evapotranspiration has been calculated using Penman-Monteith method with the help of MODIS and other ancillary data. Analysis of ET for four years shows that evapotranspiration is very high in comparison to rainfall. Maximum calculated Evapotranspiration was observed in the month of May whereas maximum rainfall is received in the month of July so only this month have maximum amount of runoff. The year 2003 shows water surplus but the remaining years were water deficit.

The outcome of research will help in understanding the hydrological component and water budget of the basin and this will also give and insight for better water, management.

Due to limitation of data we restricted our analysis to four years. For future scope the study can be repeated for some more years to analysis the climate variability.

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